



FALL 2007

A Hands-on, Interdisciplinary Laboratory Program and Educational Model to Strengthen a Radar Curriculum for Broad Distribution

MARK YEARY

School of Electrical and Computer Engineering
The University of Oklahoma

TIAN-YOU YU

School of Electrical and Computer Engineering
The University of Oklahoma

ROBERT PALMER

School of Meteorology
University of Oklahoma

MICHAEL BIGGERSTAFF

School of Meteorology
University of Oklahoma

L. DEE FINK

Instructional Consultant in Higher Education
234 Foreman Ave, Norman, OK 73069 USA

CAROLYN AHERN

Ahern and Associates
Norman, OK

KELI PIRTLE TARP

National Severe Storms Laboratory
Norman, OK

ABSTRACT

This paper describes the details of a National Science Foundation multi-year educational project at the University of Oklahoma (OU). The goal of this comprehensive active-learning and hands-on laboratory program is to develop an interdisciplinary program, in which engineering, geoscience, and meteorology students participate, which forms a community of university scholars. The program is intended to generate a unique, interdisciplinary research oriented learning environment that will train future engineers and meteorologists in the full set of competencies needed to take raw radar data to detect weather and aircraft. The program involves new coursework and is oriented around other successful programs to ensure wide distribution by many students and

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

scientists. Supported by the Division of Undergraduate Education at the NSF, the project began with a Phase I grant in the fall of 2004, which also recently received a Phase II grant to refine the project through 2010. In keeping with the global movement of electronic knowledge delivery via written, as well as visual media, several weblinks have been established for this paper.

Keywords: interdisciplinary, broad distribution, multi-function radar

INTRODUCTION

Severe and hazardous weather such as thunderstorms, downbursts, and tornadoes can take lives in a matter of minutes. In order to improve detection and forecast of such phenomena using radar, one of the key factors is fast scan capability. Conventional weather radars, such as the ubiquitous NEXRAD (Next Generation Radar developed in the 1980's), are severely limited by mechanical scanning. Approximately 175 of these radars are in a national network to provide the bulk of our weather information. Under the development for weather applications, the electronically steerable beams provided by the phased array radar at the National Weather Radar Testbed (NWRT) can overcome these limitations of the current NEXRAD radar. For this reason, phased array radar was listed by the National Research Council as one of the primary candidate technologies to supersede the NEXRAD [1]. By definition, a phased array radar is one that relies on a two-dimensional array of small antennas. Each antenna has the ability to change its phase characteristics, thus allowing the overall system to collectively locate specific interesting regions of weather. The NWRT is the nation's first facility dedicated to phased array radar meteorology, and it also has a multi-function capability to allow it to be used for detecting aircraft. In addition, the demand for students trained in this area will be high as new radar technologies replace the ones designed 20 years ago, and as weather radar usage extends into areas such as homeland security. From the Federal Aviation Administration's (FAA) perspective [2], "a multifunction radar can support weather, air traffic control, homeland defense and Department of Defense surveillance needs simultaneously. The multi-functionality is of interest to the FAA as a compliment to Automatic Dependant Surveillance—Broadcast (ADS- B) as well as a possible program cost reduction solution for its aging fleet of ground based radars." Moreover, it is consistent with one of the National Oceanic & Atmospheric Administration's (NOAA) Mission Goals for the 21st Century: to serve society's needs for weather information [3]. More details about the NWRT are available at NOAA's National Severe Storms Laboratory website. This lab is located in Norman, Oklahoma.

www.nssl.noaa.gov/research/radar/par.php



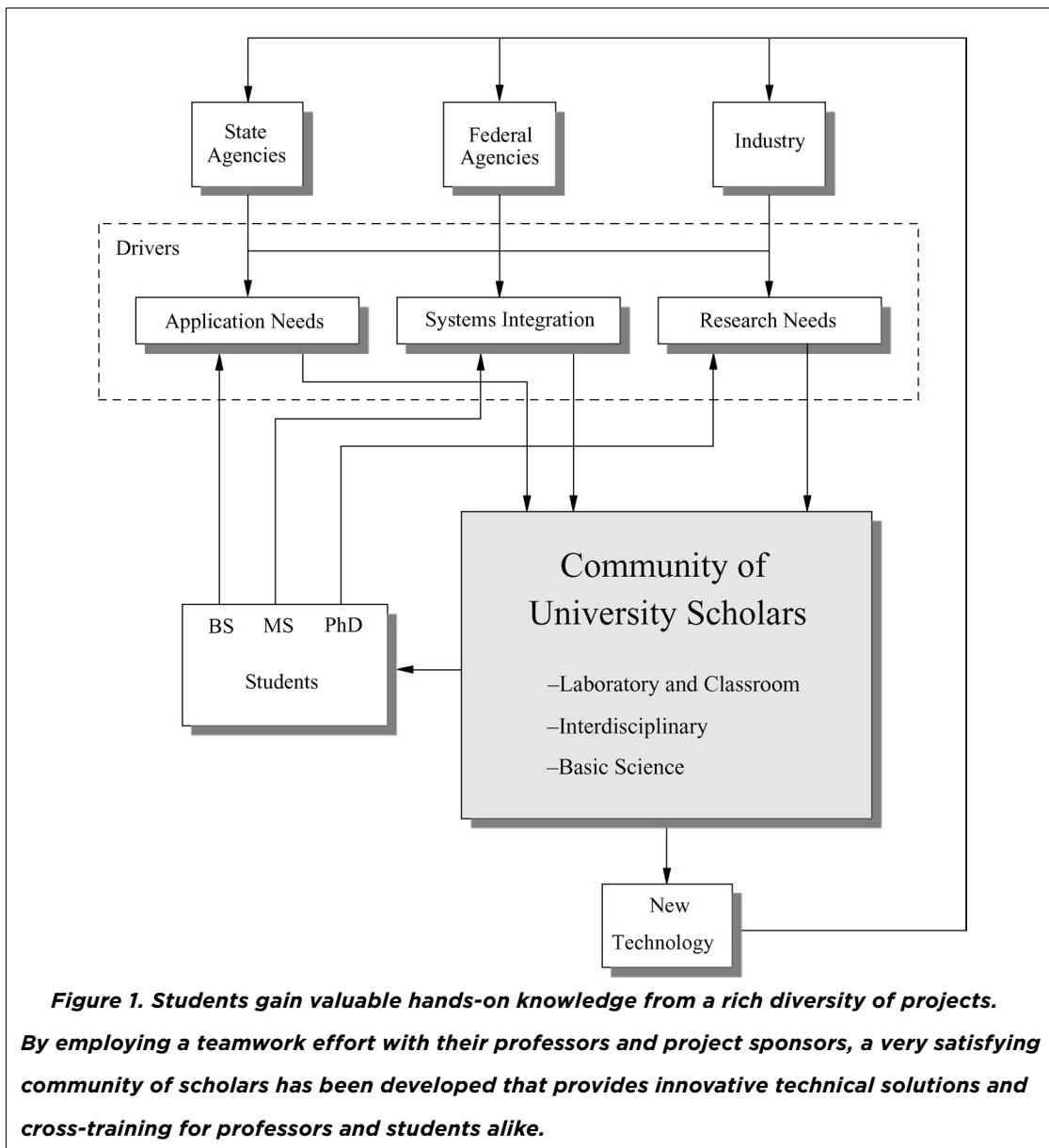
A Hands-on, Interdisciplinary Laboratory Program and Educational Model

Long-term warnings have improved greatly over the last five years and are now being used for critical decision making [4]. Further improvements are being aimed at providing longer warning lead times before severe weather events, better quantification of forecast uncertainties in hurricanes and floods, and tools for integrating probabilistic forecasts with other data sets. Many other industries, groups, and individuals use weather information. For example, the construction industry uses weather information to schedule specific activities and to purchase materials. Across the nation, middle and high school teachers use weather data to develop math and engineering skills in their students, which is essential for the future [5, 6, 7]. Following the classic Boyer Report, it is very important that no gap exists between teaching and research [8]. In addition, faculty members who creatively combine teaching with research are essential to the improvement of undergraduate education [9, 10, 11, 12]. With this in mind, we now introduce the model that governs and sustains the teaching and research mission of our university laboratory, as depicted in Figure 1. The synergistic interaction between teaching and research, their drivers and end-results is also illustrated. These drivers can be classified into those of resource needs (e.g., qualified personnel) and technology related issues. Resource needs can be further classified into three types, as noted below.

- Design and application engineers
- Radar system integrators and managers
- Research scientists

These needs are met by BS, MS, and PhD graduates, respectively. Thus our undergraduate and graduate educational initiatives have been developed to provide an appropriate level of training at the BS, MS, and PhD levels in this lab. The foundational key of the entire endeavor is the undergraduate educational process—these students are the first ones to enter our cycle that stresses lifelong learning, creativity, global awareness, and interdisciplinary collaborations. Sharing exciting projects with students naturally occurs here, since the authors have collaborative research projects at the NWRT. The laboratory/teaching program provides abundant opportunities for individuals that may concurrently assume responsibilities as researchers, educators, and students. The NWRT facilitates joint efforts that infuse education with the excitement of discovery and enrich research through a diversity of learning perspectives.

The program leverages a very successful, comprehensive outreach program that exists at OU to enhance wide distribution. The principal investigators are partnering with the Oklahoma Climatological Survey (OCS) to adapt and implement project materials directly to middle/high school teachers via the OCS EarthStorm outreach program. Established in 1992, the EarthStorm project (NSF TPE-9155306, and currently funded by the State of Oklahoma) has provided over 250 Oklahoma schools with the materials and requisite education to apply real-time environmental data in support of math, science, and engineering curricula. For nearly a decade, the OCS has implemented weather curricula

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

as part of laboratory activities for undergraduate students (NSF DUE -9981098), conducted annual summer content institutes for K-12 teachers (State of Oklahoma funded), as well as hosted dozens of K-12 student science fairs (funded by US Department of Energy). Broadly, the authors are disseminating content-rich materials to the OCS for adaptation into the math and science curricula at the 250 middle/high schools (primarily middle schools) served by the OCS's outreach programs. These materials enhance teacher and student knowledge of fundamental atmospheric and engineering topics. Specifically, weather radar content has been integrated into the OCS summer content institutes



for middle school teachers. Furthermore, teachers participating in the summer content institutes can be paired with our peer teachers in a mentorship arrangement to aid in the implementation of weather radar content into the middle school classrooms (peer teachers are discussed later). During the summer workshops, the middle school outreach have focused on basic radar fundamentals formulated around weather radar applications. For instance, in the summer of 2005, the OCS facilitated the weeklong EarthStorm Summer Institute in July. Approximately 48 teachers from 6th through 8th grade from around the state and surrounding states signed up to attend. During the preceding fall semester, our peer teachers took the courses offered by the team of professors. Then, during the spring semester, the peer teachers prepared laboratory exercises for the workshop during the summer. Finally, our assessment expert took survey data. Similarly, the team prepared materials for the EarthStorm workshop in 2006 and will do so again in 2007. Established in 1980, the OCS has a legislative mandate to acquire, process, and disseminate climate and weather data and information for use by the state's citizens. Hence, this significant organization in Norman operates a comprehensive website, and details about their outreach program are in the link below.

www.ocs.ou.edu

INTEGRATED INTERDISCIPLINARY CURRICULUM

The project is truly a cross-disciplinary effort between the School of Meteorology and the School of Electrical and Computer Engineering. This cross-fertilization between engineering and meteorology is also exemplified in efforts currently underway at our university to develop the cross-disciplinary Weather Radar and Instrumentation Curriculum. More details are available at the link below.

<http://arrc.ou.edu>

The classroom exposure to radar theory, with supportive real radar data projects, is greatly enhancing the educational experience of the students and will more thoroughly prepare them for active scientific careers. The team's efforts have culminated in the development of a revolutionary laboratory and coursework curriculum that coincides with the interdisciplinary development and integration of the School of Electrical and Computer Engineering and the School of Meteorology. A suite of courses has been developed, and where prudent, the courses were cross listed between the two departments. Cross listing has been shown to strengthen the bonds of these types of collaborative efforts, while welcoming, attracting, and retaining students [13, 14, 15]. These courses were supported by specific laboratory exercises.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

- *Introduction to Meteorology* introduces students to important phenomena and physical processes that occur in the Earth's atmosphere. Through lectures and laboratory exercises, students will learn the basic radar concepts that are used to study atmospheric problems.
- *Electromagnetic Fields* is an existing course in which modifications are currently being explored and implemented which include plane wave propagation, polarization, reflection, and an introduction to radiation/antennas—all related to the study of the atmosphere.
- *Radar Engineering* introduces various radar system designs and their applications with an emphasis on weather radar. Radar system architecture and their functionalities and limitations of subsystems are discussed.
- *Radar Meteorology* is an established course (that has been updated with new laboratory experiments) that develops the quantitative relationships between a radar and its target—i.e., interpretation of the data.
- *Weather Radar Theory and Practice* is a new course (with supporting laboratory experiments) that concentrates on fundamental radar theory and the development of conventional signal processing algorithms.
- *Adaptive Digital Signal and Array Processing* is a new course devoted to the theory of adaptive algorithms for aircraft tracking and adaptive processing of radar signals to extract meaningful weather data.
- *Remote Sensing and Experimental Design* is a class which is devoted to the placement of various remote and in-situ sensors for significant studies in the field. The coursework was carefully tailored to fit within the current degree plans of both schools.

Prerequisites have been carefully observed to welcome and retain students. Special content for the new Introduction to Meteorology course was developed and served as a point of entry into the weather radar curriculum. Next, students may take Electromagnetic Fields. Subsequent to this, students can enroll in Radar Engineering and/or Radar Meteorology. These classes were taught and coordinated to ensure student success. Finally, students take the in-depth Adaptive Digital Signal/Array Processing or the Weather Radar Theory/Practice class—which culminates all previous learning, concentrates on deep projects, and serves as a spring board into the advanced graduate level programs in both schools. These were always offered in the fall, and will continue to be. Table 1 describes a layout of the courses, which have been evolving in the program since 2004. Two out-of-department assessment experts were responsible for carefully developing assessment instruments for each course. These specially designed, lengthy surveys were based on the learning objectives of the course syllabi. More details are available at the web portal below.

<http://arrc.ou.edu/education>

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

Course	Dept	Level	Semester	Status	Cross-list
Intro. To Meteorology	METR	Soph	Spring/fall	Refined	No
Electromagnetic Fields	ECE	Jr	Spring	Refined	No
Radar Engineering	ECE	Sr	Spring	New	Yes
Radar Meteorology	METR	Sr	Spring	Refined	Yes
Weather Radar Theory/	METR	Sr	Fall	New	Yes
Adaptive DSP and Array Processing	ECE	Sr	Fall	New	Soon
Remote Sensing/Experimental Design	METR	Sr	Fall	New	Soon

Table 1. Layout of The Interdisciplinary Classes**HANDS-ON LABORATORY EXERCISES:**

Teaching modules have proven to be an effective means of introducing new material into an existing curriculum, without adding new courses [16, 17]. Moreover, the development of modules allows for the easy implementation at other institutions of learning [18]. There are many advantages to encapsulating a focused amount of material in a modular fashion, and modules were the educational cornerstone of DARPA's Rapid Prototyping of Application Specific Signal Processors program [19]. At the University of Oklahoma, the new modules, instruction, and assessment have been designed in accordance with the ABET Criteria 3 parts (a)-(k) [20]. They have also been carefully constructed to facilitate their adoption at other institutions. A few sample modules from selected courses are given below. Within the sequence of courses, the learning of scientific phenomena, such as interesting atmospheric events, is greatly enhanced when students are allowed to make measurements and construct mathematical models that govern their behavior [21]. Several teamwork-oriented laboratory modules have been integrated into each of the courses. These modules have been organized around four themes: 1.) data collection: developing different scanning patterns, 2.) data processing: computing and enhanced algorithms to extract weather information from the raw radar data, 3.) data display: placing the composite weather information on a user-friendly computer display, 4.) data interpretation: scientific understanding and discovery of the displayed data—this includes the locations and dynamics of storms, precipitation, tornados, downbursts, and the like. Each of the four items complement and build upon one another—thus solidifying the interaction between the courses. These hands-on laboratory modules are similar to the other university radar teaching methods [22, 23, 24]. The unifying themes that integrate the courses are as follows.

- Introduction and detailed study of the science of weather radar
- The engineering of data acquisition and analysis techniques
- The mathematics of weather radar processing
- The modern-day technology of displaying and interpreting weather phenomena on a conventional computer screen

A Hands-on, Interdisciplinary Laboratory Program and Educational Model



Figure 2. Students working together.

Students have an unprecedented opportunity to take advantage of a unique federal, private, state and academic partnership that has been formed for the development of the phased array radar technology at the NWRT—thus helping to complete the cycle of innovation and collaboration that is depicted in Figure 1. Several participants contributed to the installation of the new radar, including: NOAA's National Severe Storms Laboratory and National Weather Service Radar Operations Center, Lockheed Martin, U.S. Navy, Federal Aviation Administration, and BCI, Inc. The project has very favorable institutional support, since: 1.) this effort is complementary to its research mission, 2.) it has the resolute potential to affect approximately 840 students across two departments, and 3.) it produces highly sought after students (by industry and graduate programs). Within the Engineering Center on campus that houses the School of Electrical and Computer Engineering, a special classroom has been dedicated for this teaching program; see Figure 2. This classroom known as the “Undergraduate Weather Radar Computing Laboratory” for use by all of the courses and community building activities. At the current time, contemporary infrastructure in the laboratory supports our mission: 12 new computers, a new server, and associated equipment to pipe the radar’s data into this laboratory on the main campus—closely following other “client server models,” where a server runs at the radar facility and the client program operates at remote locations. Looking forward, the flexibility of this laboratory setting will allow students at other universities to duplicate our course, since a future provision will allow data to be readily downloaded from the Internet. At the time of this writing, Java scripts are currently being prepared at the NWRT for this operation. Also helping to ensure that no gap exists between teaching and research, the weblink below has an online multimedia video for viewing the radar that serves as the point of data collection for our hands-on radar laboratory.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

<http://advances.asee.org/vol01/issue01/media/05-media01.cfm>

At the current time, student activities are numerous. Computing algorithms are studied and implemented that convert radar data from the phased array radar into environmental measurements known as spectral moments—very similar to previous researchers associated with conventional rotating weather radars [25, 26, 27]. Spectral moments (*reflectivity, radial velocity, and spectrum width*) are the essential, required radar meteorological measurements that are used to make decisions about cloud locations, storms, rain fall, tornados, downbursts, hail and other important weather phenomena. Microbursts are strong downbursts of air from evolving rain-clouds which can develop in a matter of minutes and cause windshear, which are especially dangerous to aircraft [28, 29, 30]. These hazards are especially prevalent during landing, since the aircrafts operate at reduced speeds as they glide towards the runway. Through appropriate configuration of the phased array radar at the NWRT, it can be designed to provide this windshear information [28, 29, 30, 31, 32]. Although, detecting windshear is a classic problem for aircraft, many open problems exist. Up to this point, the team's work has mainly provided an image of the atmosphere surrounding the radar. In general, this will provide aircraft and other vehicles in the future an ability to make reasonable short term weather forecasts and decisions about improved situational awareness. In the dual-use mode, collecting weather information while tracking targets of homeland interest, the scan strategy of the radar will need to be devised to accommodate both targets—that is, an adaptive multiplexing operation that visits each target differently. With respect to weather, the radar does not have to radiate the entire volume every scan or sweep of the beams. Weather targets are much larger than aircraft and move at a slower rate. Understanding these concepts, and other radar related topics, is aided by hands-on teaching activities, which are discussed next.

In a recent paper by Shuman and his colleagues [33], the authors campaign for the philosophy that “One of the primary methods created to help integrate team learning into the engineering classroom is the development of formal curricular modules that could be used by various faculty planning to have students work on team projects.” In fact, universities in remote locations, such as in Puerto Rico, have relied on teaching modules for especially difficult courses [34]. As such, compelling evidence exists that indicates that students do have a positive reaction to teaching modules [35]. In addition, such modules have also been a stimulus to increased retention for women in engineering [36]. By observing other successful pedagogical programs in the US, such as the Clark School of Engineering at the University of Maryland and their modular team training program that was funded by the National Science Foundation, we can assess their strengths, while avoiding known pitfalls—thus helping to complete the cycle of innovation. The goal of their “Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS)” project was to provide a team based

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

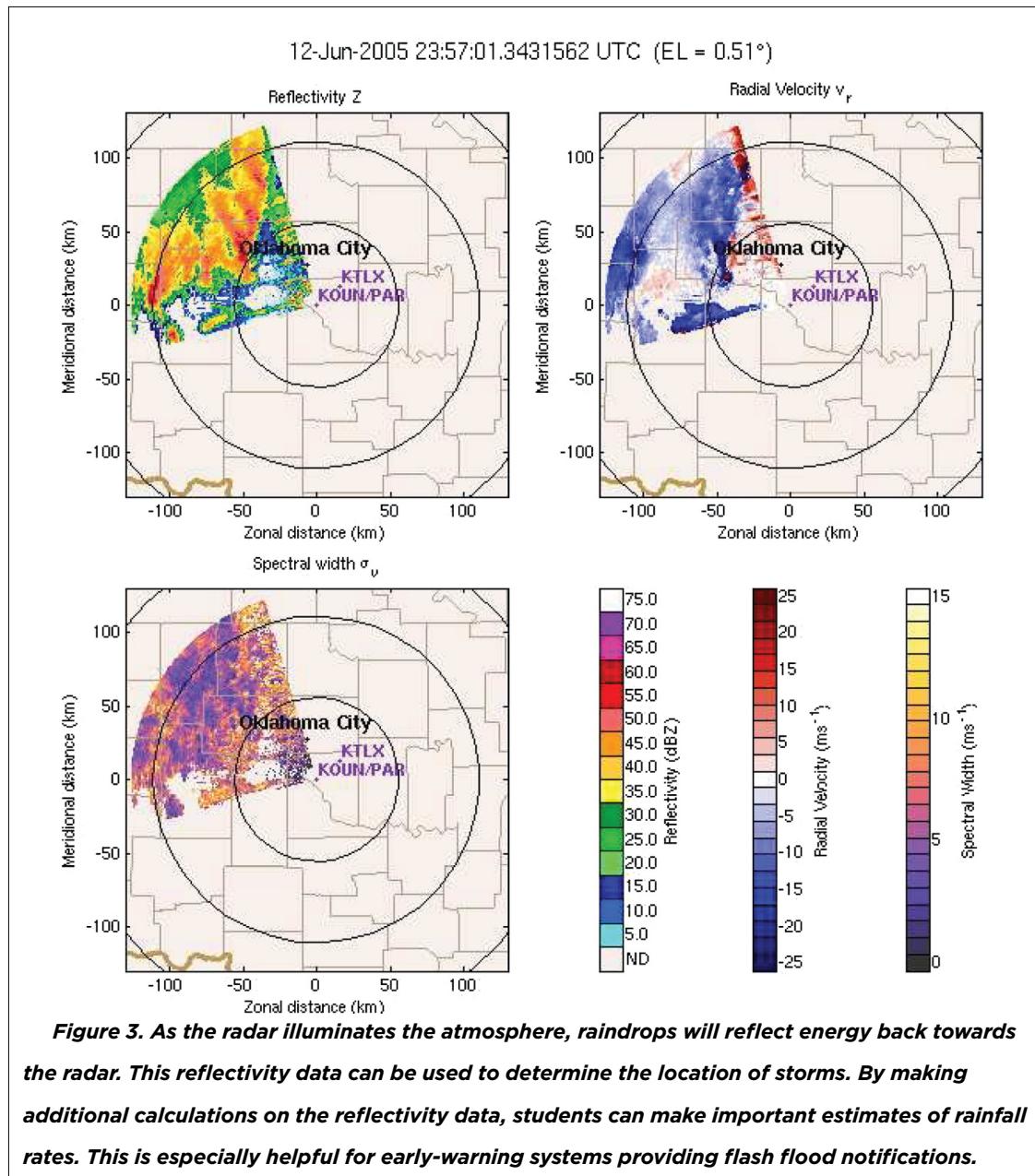
curriculum that can be easily adopted by engineering faculty from various schools and at different levels of the undergraduate curriculum [37]. A couple of our laboratory exercises are given below.

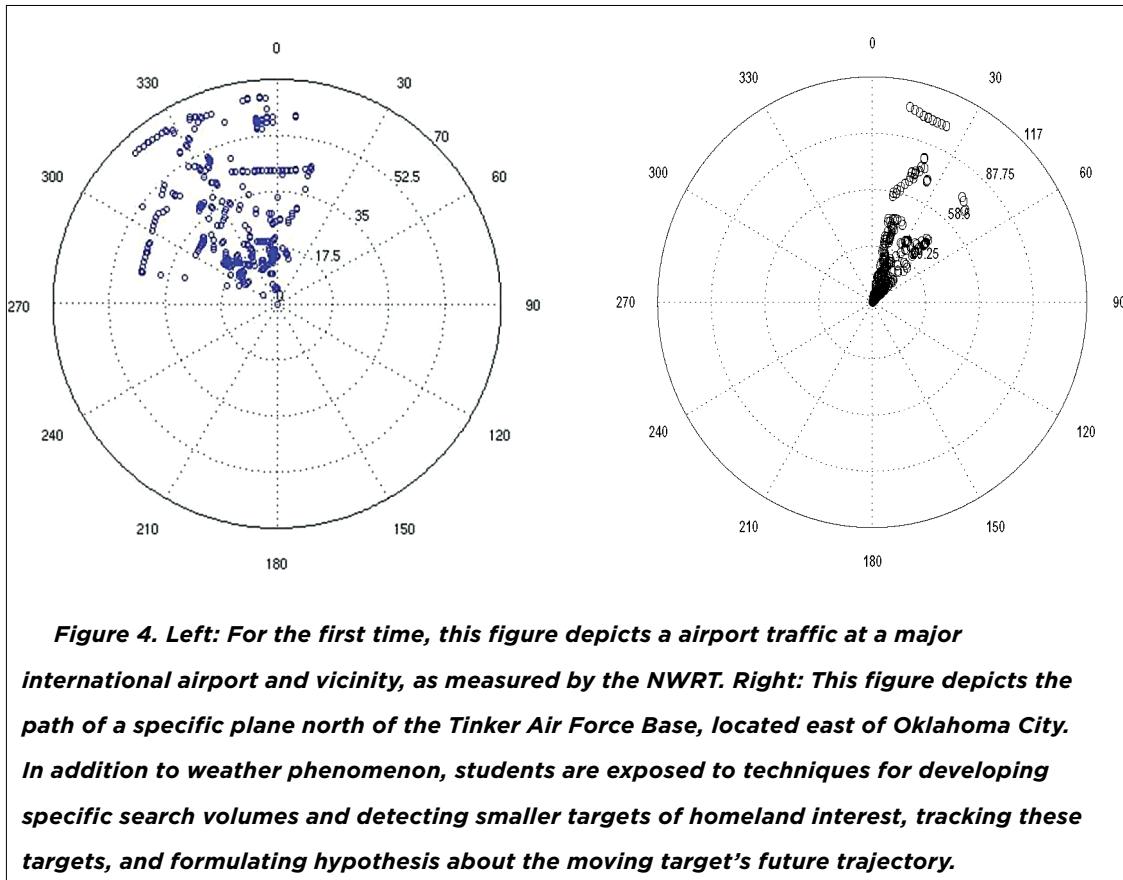
Statistical Properties of Weather Radar Data Module: This laboratory exercise is taught as a part of the Weather Radar Theory and Practice course. As eloquently articulated in the passages of the book *Engineer of 2020* [38], students will be expected to have a better understanding of the “natural world” and although natural disasters are beyond man’s control, man’s ability to predict them and adapt accordingly are essential to minimize impact. In fact, about one-third of the nation’s \$10 trillion economy is sensitive to climate variability and weather [39, 40, 41]. Predicting these natural disasters heavily depends, in part, on making decisions based on measured radar data. As such, experiential learning is a highly effective means to convey new concepts to students [42, 43, 44]; moreover, the voluminous amounts of data generated by a weather radar lends itself to this teaching strategy quite well. Expecting students to convert radar signals based on electromagnetic measurements into meaningful graphs and plots on a computer screen is something that is best learned by the students—by doing it themselves after the traditional classroom lecture and with small amounts of strategic guidance from the instructor. In this module, students investigated the NWRT data by calculating the three spectral moments for these data. Plotting the reflectivity and radial velocity gives a nearly instant snapshot of atmosphere, but more importantly, which they are combined with other variables, they can be used to initialize numerical weather prediction models. Moreover, a large number of studies by others have focused on the retrieval, often from single-Doppler radar measurements, such unobserved variables, in order to gain a full description of the state of the atmosphere, and to initialize numerical weather prediction models [45, 46, 47, 48, 49]. In addition, the students were required to study the statistical nature of these real data and compare to the theory presented in class. Based on [50], Figure 3 depicts one example of the collected and processed data from our hands-on experiments.

Multi-Function Module: On a national basis, airport capacity has increased by only 1 percent in the past 10 years, while air traffic increased 37 percent during that time, as reported by the American Society of Civil Engineers [51]. It is clear that America’s infrastructure is aging. Providing discipline specific solutions will be extremely costly. However, by working together, a diverse group of scientists and engineers can develop the individual radars can be used in a multi-function capacity to provide both weather and target tracking data. This strategic alliance greatly reduces costs, while providing enormous benefits to the public. The left side of Figure 4 depicts aircraft detection measurements using the NWRT looking towards the Will Rogers International Airport in Oklahoma City, OK [2, 52]. Here, detections were made within a 90 degree sector. The set of concentric circles denote distances in units of kilometers away from the radar. The right side of Figure 4 depicts the team’s aircraft detection measurements using the NWRT looking towards the Tinker Air Force Base, which is located east of downtown Oklahoma City. As depicted in the upper section of the graph at approximately 95 km,

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

a single trajectory has been identified after processing with an adaptive algorithm has been applied. In order to collect the data, a series of STIM or “stimulus” packets were defined that contained the details of how, where and when the radar was to operate—more details about the STIM files for the NWRT are in [53]. The data was then packaged into blocks organized by STIM. The radar collected the data from a 45 degree sector of the atmosphere over a period of several minutes. Thus for this particular experiment, both the azimuth and elevation angles were scanned from 0 to 45 degrees. For



A Hands-on, Interdisciplinary Laboratory Program and Educational Model

each radial, the data was collected at a range between approximately 2.0 km and 117.0 km; 32 pulses were emitted and received along each radial. The received signal was sampled at 5 Mbps, leading to a range gate size of approximately 60 m for a total of 1856 valid range gates. The sector was swept using the tilt and scan strategy, thus rotating the radar's beams in azimuth from 0 to 45 degrees, increasing the beam's elevation angle by one increment, and revisiting the same azimuth locations.

UNDERGRADUATE PEER TEACHERS

Developing a community of scholars is important to sustaining an active program, and engaging a broad spectrum of students is an essential thread in the fabric of this goal. We define a peer teacher to be someone who is a very energetic and motivated student; is a member of our research program and radar curriculum; and is a diverse undergraduate student. A diverse student group has been enhanced with the assistance of the Diversity Coordinator within the Multicultural Engineering

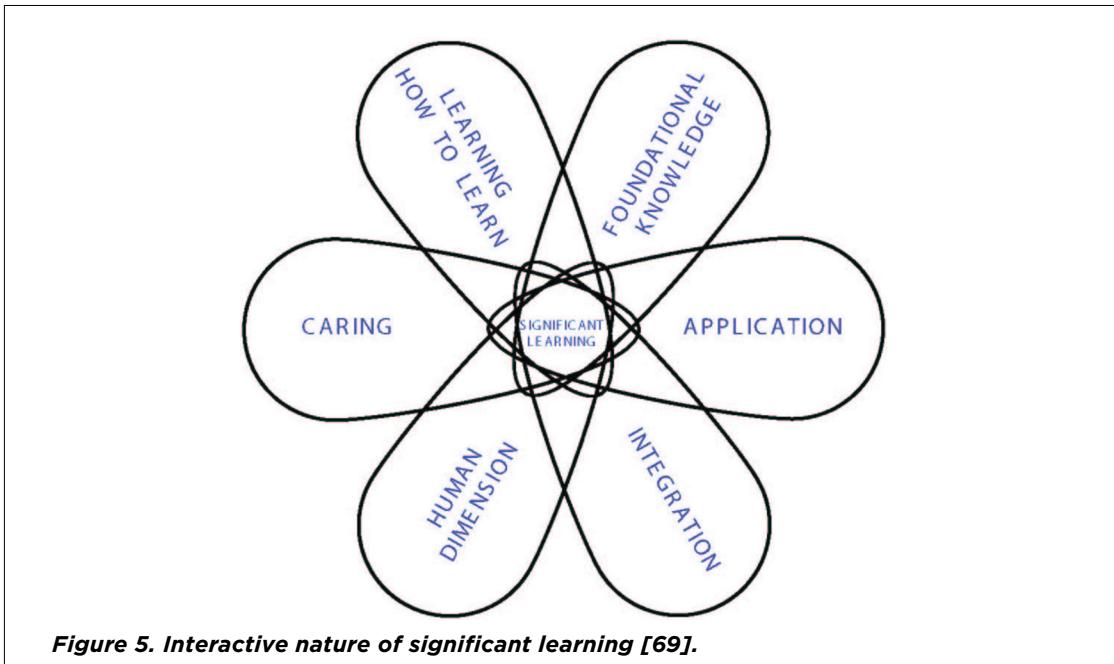
A Hands-on, Interdisciplinary Laboratory Program and Educational Model

Program (MEP) at our university. The judicious use of peer teachers has been shown to be a highly effective means to motivate and retain undergraduates in engineering [54, 55, 56]. The peer teachers have three primary duties: 1.) assist the instructor in the class/laboratory during periods of team-work activity, 2.) host tutoring sessions for fellow students outside of class/laboratory time, and 3.) assist with middle/high school outreach (described later). Since the peer teachers are close in age to the students and highly familiar with NWRT's research plan, they will be in a position to add significant value to the integrated program. During the first few semesters of our project, we have found that approximately 54% of the students who have served as a peer teacher also later joined our graduate program. Students have been organized into groups of teams and teamwork has been stressed [57]-[60]. The teammate selection will be carefully coordinated by the course instructor to ensure cross-disciplinary students. Teamwork has also been shown to increase retention [61, 62], and learning is enhanced when it resembles a team effort rather than a solo race [63]. Moreover, learning is achieved by individuals who are intrinsically tied to others as social beings, interacting as competitors or collaborators, constraining or supporting the learning process, and able to enhance learning through cooperation and sharing [64]. Various teachers have found that team-based learning can be especially helpful in classes with a high level of student diversity [65]. Team-based learning creates conditions in which people who are very different from one another learn that they need to work together. They find ways to make their differences an asset rather than a liability [65].

MERGING PEDAGOGICAL AND SCIENTIFIC LEARNING GOALS

The pedagogical goals and the curiosity driven scientific pursuits have been merged together with a taxonomy of significant learning—this strengthens the bonds of the community and helps to establish a logical framework that supports broad distribution. As originally defined by Bloom and his associates, a taxonomy is described as a “classification,” so the well-known taxonomy of learning objectives is an attempt (within the behavioral paradigm) to classify forms and levels of learning [66]. Since the pioneering work of Bloom, other taxonomies have been developed. The most often cited ones include work by Anderson and Krathwohl [67]; Wiggins and McTighe [68]; and Fink [69]. Here, our pedagogical efforts follow the philosophies of Dr. L. Dee Fink, as his work provides a methodology that comes from an understanding that individuals and organizations involved in higher education are expressing a need for important kinds of learning that do not emerge easily from the Bloom taxonomy, for example: learning communication skills, character, tolerance, the ability to adapt to change, etc. As described in [69, 70], Fink's Taxonomy of Significant Learning is oriented around the idea that each kind of learning is interactive, as illustrated in Figure 5 [69]. (See <http://www.ou.edu/pii/significant/siglearning.htm> for more detail.) This means that each kind of learning can stimulate other kinds of

A Hands-on, Interdisciplinary Laboratory Program and Educational Model



learning. As each element of the model is included in the classroom, the more each element will support their counterparts, thus increasing the significance of the learning experience [69].

EVALUATION PLAN

The courses/laboratory modules supported by this project teach students the knowledge, skills and interest necessary to transform radar data into meaningful interpretations of weather, based on information displays generated by the students themselves. Activities are included that will 1.) increase the number of middle/high school students coming to college with an interest in weather radar and 2.) enable other universities to easily adopt similar programs. The evaluation plan is designed to assess how well the courses and other activities achieve their intended purposes [71, 72, 73]. This has involved the development of questionnaires, assessment instruments, and interview protocols for each project goal. During the first year of the project, questionnaires for the baseline data were developed. In addition, the project evaluator worked with the course teachers to (a) identify all major learning goals (e.g., knowledge, application) and then (b) develop assessment procedures for appraising each kind of learning. At the end of each course, two tasks were completed: student learning was assessed by the written methods and the professors were interviewed. The latter information was used to determine such things as how satisfied the teachers were with the level of student learning and whether the work load involved in teaching the course was within acceptable limits.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

OUTREACH ASSESSMENT

Teachers participating in a recent EarthStorm workshop completed project evaluations describing what they learned from the project, the most and least helpful aspects, further information they would like to learn, concerns and suggestions, and appropriate changes. These evaluations were in the form of an extensive, written questionnaire. It is noted that the EarthStorm workshop had a duration of several days and that our materials were only a part of this comprehensive program. The assessment below summarizes the activities, while also shining light on our radar tutorials.

Information learned: Respondents were overwhelmed by the wealth of knowledge they gained from EarthStorm 2005. Respondents indicated having a new understanding of the intricacies involved in weather; participants did not previously understand the number of variables affecting weather. In addition, participants valued the information presented concerning radar data analysis and interpretation. EarthStorm presented the past, present, and future of weather radar as well as potential applications of radar data. Respondents expressed appreciation for the thorough discussion of technical applications.

Helpful aspects: EarthStorm participants found the thorough lesson plans and step-by-step instruction for classroom activities to be very useful. Several participants identified the comprehensive WeatherScope tutorial as the most useful aspect of EarthStorm. A majority of respondents identified detailed computer instruction as the most helpful feature. In order to improve EarthStorm content, survey respondents were asked to share the least helpful parts of EarthStorm. Several teachers believed that the portion of EarthStorm concerning inquiry teaching was unnecessary.

Further learning: EarthStorm generated an interest in gaining additional knowledge about weather and weather radar. Several teachers expressed curiosity about the fundamental aspects of weather; teachers wanted to learn more about basic weather elements, climate, forecasting, severe weather, tornadoes, and hurricanes. While respondents appreciated technical aspects of EarthStorm, they wanted more material covering simplified meteorology.

Appreciation, concerns, suggestions: Teachers expressed overwhelming appreciation of the friendly, knowledgeable, professional, and helpful staff. The variety of speakers provided a well-rounded week. Most respondents enjoyed the radar facility tour and weather balloon launch—similar to the events at the annual Weather Festival, which is held each fall semester. The EarthStorm participants were thankful for the impressive computer lab used throughout the project; participants could work individually on computer-based labs. Teachers appreciated the staff and service at the hotel on campus. It was clear that participants were impressed with EarthStorm material, presentation, organization, and staff. Finally, EarthStorm is offered every year. For instance, Figure 6 depicts an activity during the summer of 2006. In addition to the OCS website mentioned previously, searching it points to a website with more detailed information.

<http://earthstorm.ocs.ou.edu>

A Hands-on, Interdisciplinary Laboratory Program and Educational Model



Figure 6. Peer teachers work with middle and high school teachers during outreach activities. The fundamentals of radars are being taught in this exercise to determine the speed of a moving ball.

SUMMARY

This paper describes the curriculum details of a National Science Foundation (NSF) multi-year project at the University of Oklahoma. Supported by the Division of Undergraduate Education at the NSF, the project began with a Phase I Course, *Curriculum, and Laboratory Improvement* (CCLI) grant in the fall of 2004, which also recently received a Phase II CCLI grant to extend and refine the project through 2010. This comprehensive active-learning and hands-on laboratory program is an interdisciplinary program, in which engineering, geo-science, and meteorology students are encouraged to actively participate. The program is intended to generate a unique, interdisciplinary research-oriented learning environment that will train future engineers and meteorologists in the full set of competencies needed to take raw radar data and transform it into meaningful interpretations of weather phenomena. The heart of the program is the development of a set undergraduate courses, offered by the School of Meteorology and the School of Electrical & Computer Engineering, that provide hands-on laboratory experiences in the special knowledge and skills necessary for organizing real-time weather data and aircraft detections, improving and preparing that data for display, and interpreting its meteorological and scientific significance. In addition, programs are

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

available for middle/high school students for the purpose of increasing their interest in science and engineering prior to entering college. Future works are many, including: efforts to interest other university departments in building similar or related curricula in their programs, the development of more teaching modules, putting the teaching modules on the web, and continuing to welcome students to participate in interdisciplinary projects—as discussed next.

The combination of high-performance computing and emerging radar systems provide a new window through which researchers can observe the natural world at a fidelity that could only be imagined a few years ago. As the future unfolds, the team will focus on these issues, as encouraged by the Boyer Report mentioned earlier. For instance, enhancements to storm tracking and short-time prediction will leverage the efficiency of real-time spectral moment calculations, in-depth raw data analysis, and innovative tracking techniques. It is anticipated that this trifecta can be gauged against contributions to these problems, which include [74, 75, 76], with an eye to the future of advanced nowcasting [77, 78, 79]. These activities will form the basis of MS/PhD projects and are excellent extensions of undergraduate programs. Before students can address these issues, new learning materials that can be quickly absorbed must be developed, whose development is guided by research on teaching. The educational taxonomy provides an excellent, balanced structure for this portfolio of diverse needs. The glue that holds this rich tapestry together is this taxonomy and our learning community. In a broader sense, the community involves university, federal, and industrial fellowship.

ACKNOWLEDGEMENT

Partial support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement program under Phase I grant NSF-0410564 and Phase II grant NSF-0618727. Eight participants contributed to the installation of the new radar in Norman, OK. These are: NOAA's National Severe Storms Laboratory and National Weather Service Radar Operations Center, Lockheed Martin, U.S. Navy, University of Oklahoma's School of Meteorology and School of Electrical and Computer Engineering, Oklahoma State Regents for Higher Education, the Federal Aviation Administration, and Basic Commerce & Industries. Additional acknowledgement is also extended to the National Severe Storms Laboratory for making the video for this paper.

REFERENCES

[1] National Research Council Committee on *Weather Technology Beyond NEXRAD*. Washington, DC: National Academy Press, 2002.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

[2] W. Benner, G. Torok, M. Batista-Carver, and T. Lee, "MPAR program overview and status," paper 7.1, pp. 1-13, *American Meteorological Society*, Annual Meeting, January 2007.

[3] National Oceanic and Atmospheric Administration, *New Priorities of the 21st Century*, www.noaa.gov, pp. 1-23. March, 2003.

[4] National Research Council, *Making Climate Forecasts*. Washington, DC: National Academy Press, 1999.

[5] National Science and Technology Council, *Ensuring a Strong U.S. Scientific Technical and Engineering Workforce in the 21st Century*, Washington, DC: Office of Science and Technology Policy. 2000.

[6] National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late*, Washington, DC: U.S. Department of Education. 2000. Available at <http://www.ed.gov/americancounts/glenn>

[7] T. Camp, "The incredible shrinking pipeline," *Communications of the ACM*, vol. 40, no. 10, pp. 103-110, 1997.

[8] Boyer Commission on Educating Undergraduates in the Research University. Shirley Strum Kenny, Chair, University of Stony Brook. *Reinventing Undergraduate Education: Three Years After the Boyer Report*, 2002.

[9] National Science Foundation, "Course, Curriculum, and Laboratory Improvement," www.nsf.gov, NSF 03-558, 2003.

[10] B. Moskal, D. Lasich, N. Middleton, "Science Related Degrees: Improving the retention of women and minorities through research experience, mentoring and financial assistance," *Proceedings of the American Society for Engineering Education Annual Conference*, session 1392, pp. 1-11, 2001. http://www.asee.org/acPapers/00869_2001.PDF

[11] D. Niemeier, R. Boulanger, P. Bayly, S. Schmid, K. Muraleetharan, and A. Barros, "Integration of engineering education and research: perspectives from the NSF civil and mechanical systems 1998 CAREER workshop," *Journal of Engineering Education*, pp. 199-202, April, 2001. <http://www.asee.org/publications/iee/PAPERS/display.cfm?pdf=386.pdf>

[12] A. Jenkins, R. Breen, R. Lindsay, and A. Brew, *Reshaping Teaching in Higher Education: Linking Teaching and Research*, London, Kogan Page, and Educational Development Association. Distributed by Stylus in the USA. 2003.

[13] A. Kenimer and J. Morgan, "Building community through clustered courses," *Proceedings of the ASEE Annual Conference*, 2002. http://www.asee.org/acPapers/2002-1226_Final.pdf

[14] P. R. Backer and S. Bates, "Introduction to product design and innovation: a cross-disciplinary mini curriculum," *Proceedings of the ASEE Annual Conference*, pp. 1-10, 2005. http://www.asee.org/acPapers/2005-174_Final.pdf

[15] J. Frolik and T. Keller, "Wireless sensor networks: an interdisciplinary topic for freshman design," *Proceedings of the ASEE Annual Conference*, pp. 1-7, 2005. http://www.asee.org/acPapers/2005-278_Final.pdf

[16] W. Perry, V. Baracas, and D. Clough, "Implementing Computational Methods into Classes throughout the Undergraduate Chemical Engineering Curriculum," *Proceedings of the ASEE Annual Conference*, Session 3613, pp. 1-9, 1999. <http://www.asee.org/acPapers/99conf262.PDF>

[17] B. Mauldin, T. Reed-Rhoads, "Measuring cognitive and affective performance in a statistics course that uses online computer statistics modules," *Proceedings of the ASEE Annual Conference*, pp. 1-22, Session 1665, 2001. http://www.asee.org/acPapers/00664_2001.PDF

[18] C. Hendrickson, N. Conway-Schempf, H. Matthews, F. McMichael "Green design educational modules and case studies," *Proceedings of the ASEE Annual Conference*, pp. 1-17, Session 2451, 2000. <http://www.asee.org/acPapers/20274.pdf>

[19] V. Madisetti, A. Gradient, J. Stinson, J. Aylor, R. Klenke, H. Carter, T. Egolf, M. Salinas, T. Taylor, "DARPA's digital system design curriculum and peer-reviewed educational infrastructure," *Proceedings of the ASEE Annual Conference*, Session 1232, pp. 1-15, 1997. <http://www.asee.org/acPapers/00716.pdf>

[20] "Engineering Criteria 2000," Accreditation Board for Engineering and Technology. <http://www.abet.org/EAC/eac2000.html>, December 1998.

[21] G. Nelson, "Science literacy for all in the 21st century," *Educational Leadership*, vol. 57, no. 2, October, 1999.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

[22] V. Chandrasekar, D. Brunkow, A. Jayasumana, S. Bolen, "Development of a virtual radar environment," *International Geoscience and Remote Sensing Symposium*, vol. 6, pp. 2599-2601. July, 2001.

[23] K. Gojara, S. Bolen, V. Chandrasekar, "Undergraduate research on remote sensing at Colorado State University," *International Geoscience and Remote Sensing Symposium*, vol. 6, pp. 2757-2758. July, 2001.

[24] V. Bringi and V. Chandrasekar, "The CSU-CHILL fully polarimetric s-band weather radar facility: Providing research experience to undergraduates," *International Geoscience and Remote Sensing Symposium*, vol. 2, pp. 954-956. July, 1997.

[25] R. Doviak and D. Zrnic, *Doppler Radar and Weather Observations*, 2nd edition, San Diego: Academic Press, 1993.

[26] R. Rinehart, *Radar for Meteorologists*, 4th edition, Columbia, MO: Rinehart Press, 2004.

[27] V. Bringi and V. Chandrasekar, *Polarimetric Doppler Weather Radar: Principles and Applications*, 1st edition, Cambridge University Press, 2001.

[28] G. Stimson, *Airborne Radar*, 2nd Edition, Scitech Publishing: New Jersey, 1998.

[29] K. Lai, I. Longstaff, G. Callaghan, "Super-fast scanning technique for phased array weather radar applications," *IEE Proceedings of Radar, Sonar and Navigation*, vol. 151, issue 5, pp. 271-379, October 2004.

[30] F. Nathanson, *Radar Design Principles*, McGraw-Hill: New York, 1991.

[31] M. Skolnick, *Introduction to Radar Systems*, 3rd edition, New York: McGraw Hill, 2002.

[32] R. Keeler and C. Hwang, "Pulse compression for weather radar," *IEEE International Radar Conference*, pp. 529-535, May 1995.

[33] L. Shuman, M. Besterfield-Sacre, J. McGourty, "The ABET 'professional skills'—can they be taught? can they be assessed?," *Journal of Engineering Education*, ASEE, vol. 94, no. 1, pp. 41-55, January 2005. <http://www.asee.org/publications/jee/PAPERS/display.cfm?pdf=250.pdf>

[34] J. Colom and S. Cruz Pol, "Remote sensing modules to increase interest in traditional difficult courses," *IGARSS Symposium*, Sydney, Australia, 2001.

[35] R. Pimmel, R. Leland, and H. Stern, "Student evaluation of instructional modules on EC 2000 criteria 3 (a)-(k) Skills," *Proceedings of the ASEE Annual Conference*, Montreal, Quebec. Session 2532, pp. 1-11, 2002. http://www.asee.org/acPapers/2002-1056_Final.pdf

[36] S. M. Bartolomei-Suárez and S. Cruz-Pol, "An electrical engineering module for women in engineering," *Proceedings of the ASEE Annual Conference*, Nashville, TN, 2003. http://www.asee.org/acPapers/2003-504_Final.pdf

[37] L. Schmidt, J. Schmidt, C. Colbeck, D. Bigio, P. Smith, and L. Harper, "Engineering students and training in teamwork: how effective?" *Proceedings of the ASEE Annual Conference*, 2003. http://www.asee.org/acPapers/2003-586_Final.pdf

[38] National Academy of Engineering, *The Engineer of 2020*. National Academy Press, 2004.

[39] National Research Council, *The Atmospheric Sciences Entering the Twenty First Century*. National Academy Press, 1998.

[40] Bureau of Economic Analysis, 2002: *GDP by Industry*. www.bea.gov/bea/dn2/gpo.htm

[41] J. Dutton, "Opportunities and priorities in a new era for weather and climate services," *Bulletin of American Meteorology Society*, vol. 83, pp. 1303-1311. 2002.

[42] D. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*, Englewood Cliffs, N.J.: Prentice-Hall, 1984.

[43] M. Bailey and J. Chambers, "Using the experiential learning model to transform an engineering thermodynamics course," *ASEE/IEEE Frontiers in Education Conference*, session T2F, pp. 1-6, 2004. <http://fie.engrng.pitt.edu/fie2004/index.htm>

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

[44] J. Bruce, J. Harden, and R. Reese, "Cooperative and progressive design experience for embedded systems," *IEEE Transactions on Education*, vol. 47, no. 1, pp. 83-92, February, 2004.

[45] J. Sun, D. Flicker, and D. Lilly, "Recovery of three-dimensional wind and temperature fields from simulated single Doppler radar data," *Journal of Atmospheric Sciences*, vol. 48, pp. 876-890, 1991.

[46] Y. Lin, P. Ray, and K. Johnson, "Initialization of a modeled convective storm using Doppler radar-derived fields," *Monthly Weather Review*, vol. 121, pp. 2757-2775, 1993.

[47] Q. Xu and C. Qiu, "Adjoint-method retrievals of low altitude wind fields from single-Doppler reflectivity and radial-wind data," *Journal of Atmospheric and Oceanic Technology*, vol. 12, pp. 1111-1119, 1995.

[48] J. Gao, M. Xue, Z. Wang, and K. K. Droegemeier, "The initial condition and explicit prediction of convection using ARPS adjoint and other retrievals methods with WSR-88D data," *12th Conf. Num. Wea. Pred., Amer. Meteor. Soc.*, pp. 176-178, 1998.

[49] A. Shapiro, P. Robinson, J. Wurman, and J. Gao, "Single-Doppler velocity retrieval with rapid-scan radar data, *Journal of Atmospheric and Oceanic Technology*, vol. 20, pp. 1758-1775, 2003.

[50] R. Palmer, *Weather Radar Theory*, class notes, University of Oklahoma, fall 2005.

[51] American Society of Civil Engineers, *Report Card for America's Infrastructure*, www.asce.org, 2003.

[52] M. Yeary, B. McGuire, Y. Zhai, D. Forsyth, W. Benner, and G. Torok, "Target tracking at the National Weather Radar Testbed: A progress report on detecting and tracking aircraft," paper 8.1a, pp. 1-6, *American Meteorological Society*, Annual Meeting, January 2007.

[53] S. Katz, J. Melody, T. Maese, T. Hodge, W. Sabin, V. Chekalin, C. Savcak, J. Halenar, and W. Hock, "Radar control architecture for the national weather radar testbed," *Preprints, 19th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, CD-ROM, *American Meteorological Society*. Long Beach, CA, 2003.

[54] J. Morgan, A. Kenimer, T. Kohutek, J. Rinehart, and M. Lee, "Peer teacher from an instructor's perspective," *Proceedings of the Frontiers in Education Conference*, 2002. <http://fie.engrng.pitt.edu/fie2002/index.htm>

[55] R. Caso, C. Clark, J. Froyd, A. Inam, A. Kenimer, J. Morgan, and J. Rinehart, "A systemic change model in engineering education and its relevance for women," *Proceedings of the ASEE Annual Conference*, 2002. http://www.asee.org/acPapers/2002-2019_Final.pdf

[56] A. Garcia, G. Keller, A. McHenry, and F. Begay, "Enhancing underrepresented student opportunities through faculty mentoring and peer," *Proceedings of the ASEE Annual Conference*, 1998. <http://www.asee.org/acPapers/00201.pdf>

[57] L. Michaelsen, W. Watson, J. Cragin, and L. Fink, "Team learning: A potential solution to the problem of large classes," *Exchange: The Organizational Behavior Teaching Journal*, vol. 7, pp. 13-22, 1982.

[58] L. Michaelsen, "Team learning: A comprehensive approach for harnessing the power of small groups in higher education," *To Improve the Academy*, vol. 11, pp. 107-122, 1992.

[59] L. Michaelsen, L. Fink, and A. Knight, "Designing effective group activities: lessons for classroom teaching and faculty development," *To Improve the Academy*, vol. 16, pp. 373-398, 1997.

[60] E. Seat and S. Lord, "Enabling effective engineering teams: A program for effective interaction skills," *J. Eng. Educ.*, vol. 88, no. 4, pp. 385-390. 1999. <http://www.asee.org/publications/jee/PAPERS/display.cfm?pdf=264.pdf>

[61] D. Moxley, A. N.-Durack, and C. Dumbrigue, "Keeping Students in Higher Education: Successful Practices and Strategies for Retention," Sterling, VA: Stylus Publishing, 2001.

[62] William Koolsbergen, "Approaching Diversity: Some Classroom Strategies for Learning Communities," *Peer Review*, Summer/Fall Edition, 2001.

[63] A. Chickering and Z. Gamson, "Seven Principles of Good Practice in Undergraduate Education." (revisions: 1987, 1991, 1999). First published in the March, 1987 edition of the *AAHE Bulletin*.

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

[64] S. Engelkemeyer and S. Brown, "Powerful partnerships: A shared responsibility for learning." *American Association for Higher Education Bulletin*, pp. 10-12, October, 1998.

[65] L. Michaelsen, A. Knight, and L. Fink (editors), *Team-Based Learning: A Transformative Use of Small Groups in College Teaching*, Sterling, VA: Stylus Publishing, 2003.

[66] B. Bloom (editor), *Taxonomy of Educational Objectives, the Classification of Educational Goals—Handbook I: Cognitive Domain*, New York: McKay, 1956.

[67] L. Anderson and D. Krathwohl (editors), *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, New York: Longman, 2001.

[68] G. Wiggins, *Educative Assessment: Designing Assessments to Inform and Improve Student Performance*, San Francisco, California: Jossey-Bass, 1998.

[69] L. Fink, *Creating Significant Learning Experiences*, San Francisco, CA: Jossey-Bass, 2003.

[70] L. D. Fink, S. Ambrose, and D. Wheeler, *Journal of Engineering Education*, ASEE, vol. 94, no. 1, pp. 185-194, January 2005.

[71] J. Bransford, A. Brown, and R. Cocking (editors), *How People Learn: brain, Mind, Experience, and School*, National Research Council. Washington, DC: National Academy Press, 2000.

[72] T. Angelo and P. Cross, *Classroom Assessment Techniques*, 2nd ed., San Francisco, CA: Jossey-Bass, 1993.

[73] B. Bloom, J. Hastings, and G. Madaus, *Handbook of Formative and Summative Evaluation of Student Learning*, New York: McGraw-Hill, 1971.

[74] D. Cheng, R. Mercer, J. Barron, and P. Joe, "Tracking fuzzy storm centers in Doppler radar images," *Proceedings of the IEEE International Conference on Image Processing*, vol. 2, pp. 959-962, September 1996.

[75] T. Perry, "Tracking weather's flight path," *IEEE Spectrum*, vol. 37, no. 9, pp. 38-45, September 2000.

[76] J. Johnson, P. MacKeen, A. Witt, E. Mitchell, G. Stump, M. Elts, and K. Thomas, "The storm cell identification and tracking algorithm: an enhanced WSR-88D algorithm," *Weather Forecasting*, vol. 13, pp. 263-276, 1998.

[77] Joint Action Group for Phased Array Radar Project, Interdepartmental Committee for Meteorological Services & Supporting Research, and the Committee for Cooperative Research, *Federal Research and Development Needs and Priorities for Phased Array Radar*, FCM-R25-2006, pp. 1-119, published by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), June 2006.

[78] S. Robinson, "Utility of Tactical Environmental Processor (TEP) as a Doppler At-Sea Weather Radar," *MS Thesis*, Naval Postgraduate School, June 2002.

[79] D. Jankowski and N. Fox, "Nowcasting of storm duration," *AMS 32nd Conference on Radar Meteorology*. Albuquerque, NM, October 2005.

AUTHORS

Dr. Mark Yeary is an Assistant Professor in the School of Electrical and Computer Engineering at the University of Oklahoma. He has many years of experience as a teaching assistant, lecturer, and assistant professor. Since January of 1993, he has taught many students in various laboratories and lecture courses, culminating in approximately 11 years of teaching experience. For the 1999-00 academic year, he received the Outstanding Professor Award, given by the Texas A&M

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

student chapters of IEEE and Eta Kappa Nu, and IBM in Austin. His research and teaching interests are in the areas of customized embedded DSP systems and digital signal processing as applied to radar signal processing, image processing, adaptive filter design, and real-time systems. His applied signal processing contributions are many, and include the design an all-digital system-on-a-chip scheme for a Ka band radar and various target tracking algorithm developments for phased array systems. www.ou.edu/yeary

Dr. Tian-You Yu is an Assistant Professor in the School of Electrical and Computer Engineering. His education at the University of Nebraska and post-doc experience at the National Center for Atmospheric Research in Boulder, Colorado provide a unique cross-disciplinary background of atmospheric research. He has many reviewed technical journal and conference papers in the areas of applications of signal processing techniques to radar problems and studies using atmospheric radars. In parallel with his technical strength, he has a passion for delivering high quality education. He has developed and taught several undergraduate and graduate courses at the University of Oklahoma. <http://ece.ou.edu/people/faculty/yu.htm>

Dr. Robert Palmer has published extensively in the general area of radar remote sensing of the atmosphere, with emphasis on the use of multiple frequencies/receivers for interferometry and generalized imaging problems. He has taught courses from the freshman to the graduate level in signals and systems, random processes, and weather radar for 13 years. He has won the University of Nebraska-Lincoln (UNL) College of Engineering Faculty Teaching Award and has twice been recognized by the UNL Teaching Council for contributions to students. Prof. Palmer moved to the University of Oklahoma (OU) in the summer of 2004. After coming to OU, he led the development of a cross-disciplinary curriculum in weather radar and instrumentation between the School of Meteorology and the School of Electrical and Computer Engineering. This program has seen heavy enrollments since its inception and is currently expanding and evolving to meet the needs of both undergraduate and graduate students. He recently received the Teaching Scholars Initiative (TSI) award from the University of Oklahoma. <http://arrc.ou.edu/-rpalmer/>

Dr. Michael Biggerstaff is the lead scientist behind the Shared Mobile Atmospheric Research and Teaching (SMART) radar program, a collaborative effort between the University of Oklahoma, Texas A&M University, Texas Tech University, and the National Severe Storms Laboratory that built and successfully deployed two mobile radars to enhance storm research and to improve meteorological education. Dr. Biggerstaff has received awards in teaching and advising. He received several invitations for short courses in the U.S. and abroad. http://weather.ou.edu/faculty_details.php?FacID=24

A Hands-on, Interdisciplinary Laboratory Program and Educational Model

Dr. L. Dee Fink, an off-campus evaluator, is the person responsible for developing and implementing the evaluation plan, and he has an extensive background in pedagogy and assessment. Because of this expertise, Dr. Fink has been instrumental for: 1.) developing and monitoring the pedagogical models being used, 2.) leading the orientation programs for both undergraduate peer teachers and the faculty members involved, to make sure they fully understand the pedagogy procedures being used, 3.) developing the evaluation plan and materials, 4.) collecting and analyzing the evaluation data. <http://www.finkconsulting.info/>

Dr. Carolyn Ahern, Assessment Coordinator, earned her B.A. in English from Ohio Wesleyan and her M.A. and Ph.D. in English from Cornell University. She also holds an M.B.A. from the University of Oklahoma. For the last 20 years, she has specialized in the design, implementation, and assessment of educational materials. Most recently, she has been the coordinator of assessment for two NSF grants at the University of Oklahoma: Sooner City (Civil and Environmental Engineering) and the Course, Curriculum, and Laboratory Improvement Project (the School of Electrical and Computer Engineering and the School of Meteorology).

Keli Pirtle Tarp is the Public Affairs Specialist for the five National Oceanic and Atmospheric Administration (NOAA) Weather Partners in Norman: the National Severe Storms Laboratory, the Storm Prediction Center, the National Weather Service Norman Forecast Office, the NEXRAD Radar Operations Center and the Warning Decision Training Branch. As one example on her long list of achievements, Ms. Keli Tarp was awarded the NOAA Administrator's Award "for successfully promoting the NOAA/NWS mission and helping save lives by educating the public of the hazards of severe weather" in 2002. Keli is a past president of the Public Relations Society of America, Oklahoma City Chapter. She earned accreditation (APR) from PRSA in 1997 and re-accreditation in 2000, and has won several Upper Case Awards for writing and publications.

Address Correspondence to:

Mark Yeary
School of Electrical and Computer Engineering
The University of Oklahoma—202 W. Boyd, Room 219
Norman, OK 73019
yeary@ou.edu